Mammalian Biology
Zeitschrift für Säugetierkunde
www.elsevier.de/mambio

Original investigation

Seasonal activity patterns and movements of the raccoon dog, a vector of diseases and parasites, in southern Finland

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Receipt of Ms. 29.3.2006
Acceptance of Ms. 13.10.2006

Abstract

Activity patterns and movements of raccoon dogs (*Nyctereutes procyonoides*) were studied in Virolahti, southeast Finland, in 2000–2003. Activity data were compared to those collected from Evo, south-central Finland, in 1990–1993. Activity in winter was compared to weather (temperature and snow depth), day length and moon. Also circadian activity rhythm was studied in Evo. Raccoon dogs moved fastest in late winter after winter dormancy and slowest in autumn before settling in their winter dens. In March, males were moving more often than females. Raccoon dogs stayed usually in their dens in mid-winter (December–February) but were sometimes wandering around also during the harshest months of the year and changed their winter den on average three times. Both day length and weather affected the activity of raccoon dogs in winter. Animals usually stayed in their dens, when temperature was below −10 °C, snow depth >35 cm and day length <7 h and were moving around, when temperature was >0 °C, there was no snow and day length was >10 h. Day length and snow depth together predicted rather well the probability of animals being active during winter. Although raccoon dogs were more often active at night than during the light hours, they also showed rather much diurnal activity.

Key words: *Nyctereutes procyonoides*, activity, movements, diseases, Finland

Introduction

The raccoon dog (*Nyctereutes procyonoides*) is an alien species in Europe, introduced to the western parts of the former Soviet Union in the first half of the 20th century (Lavrov 1971; Helle and Kauhala 1991). It is the only member of the Canid family showing winter lethargy in areas where winters are harsh (Kauhala and Saeki 2004) and stores large fat reserves before winter sleep (Kauhala 1993). Females come into oestrus after awaking from winter lethargy, usually in March (Helle and Kauhala 1995). Most pups are born in May after 9 weeks pregnancy. Pups remain in the den for about 6 weeks, males spending more time with them at the den than females (Kauhala et al. 1998). Pups start to move with their parents usually in late June or early July. Dispersal of juveniles starts in August,

doi:10.1016/j.mambio.2006.10.006
Mamm. biol. 72 (2007) 6 · 342–353

most juveniles leaving their natal home range in September or October (Kauhala et al. 1993).

Raccoon dog is a vector of some dangerous diseases and parasites. The role of the raccoon dog as a vector of rabies has increased in recent years, especially in the Baltic States; in Estonia about 50% of wildlife rabies cases are today found in raccoon dogs (WHO 2004). During rabies epizootic in Finland in the late 1980s raccoon dog was the main vector/victim of the disease (Westerling 1991). Also canine distemper has been observed in raccoon dogs (Machida et al. 1993). Moreover, raccoon dogs are potential vectors of the dangerous parasite, *Echinococcus multilocularis*, since some infected raccoon dogs have been found in Germany. *E. multilocularis* is spreading northwards in Europe and is now found as far north as in Estonia (Moks et al. 2005). Raccoon dogs are also reservoirs and vectors of other parasites, such as *Sarcoptes scabiei* (Shibata and Kawamichi 1999; Ninomiya and Ogata 2005) and *Trichinella* spp. (Oksanen et al. 1998; Oivanen et al. 2002).

The present study is part of a larger project, the aim of which is to collect ecological data (density, home ranges, habitat use, activity patterns, movements and contacts between individuals) of a carnivore community in southeast Finland in order to calculate rabies models for northeast Europe. In this study we investigate the activity patterns and movements of raccoon dogs in different seasons. We also compare the activity of animals in winter with some environmental factors (weather, day length, moon).

Material and methods

Study areas

The main study area (ca. 54 km^2) was located to Virolahti, southeast corner of Finland (60°32′N, 27°41′E; Fig. 1). The area is a mosaic of small coniferous and mixed forests, tiny patches of deciduous forest and large fields bordered by wide ditches. Reed beds along the seashore are typical to the area. A small village is located in the middle of the area. The mean temperature of the year during the study was 4.8 °C, −6.3 °C in January and 18.8 °C in July. The ground was covered with snow from late November or December, depending on the year, until mid-April. The mean snow depth in January–March was 25 cm (range 3–49 cm), the mean depth at the end of March being 14 cm. Raccoon dogs were hunted in the area.

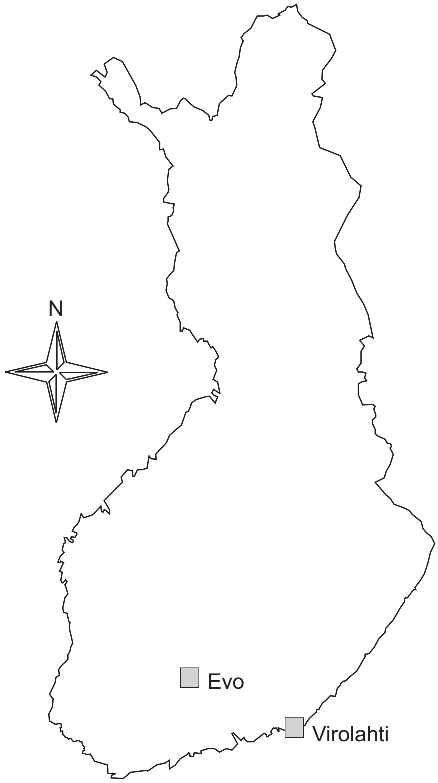

Fig. 1. Study areas in Finland.

The other study area (120 km^2) was located to Evo, south-central Finland (61°14°N, 25°10′E). It consists mainly of coniferous forest with many small lakes and streams, some clear-cuts and small pine swamps but only few fields. The mean temperature of the year was 2.6 °C, −5.2 °C in January and 16.4 °C in July. Snow covers the earth usually from late November until late April, the mean snow depth at the end of March being 25 cm, indicating later thaw in Evo than in Virolahti. Raccoon dogs were not hunted in the area.

Radio tracking

Activity patterns and movements of raccoon dogs were studied using radio-telemetry in 2000–2003 in

Virolahti and in 1990–1993 in Evo. We captured the animals mainly using wired traps. The animals were weighed, sexed and fitted with radio-collars (Virolahti: model TW-3, 138–138.5 MHz, Biotrack, Dorset, UK; Evo: 230–231 MHz, Televilt, Sweden) and plastic ear-tags (sheep tags, Dalton, UK). Transmitter life was about 1 year. The age (young/adult) of animals was estimated with the help of body weight, teeth and by palpation of the prominence of the ulna (the distal epiphyseal cartilage of the ulna, see Kauhala and Helle 1990). Only adults were fitted with radio-collars.

We located the animals from a truck with a Yagi-type antenna. Bearings were taken from at least two points, keeping the time interval between the bearings as short as possible, usually about 5 min, to minimize the error caused by animals' movements. Mean distance between the tracker and the animal was 563 m (290–910 m) in a random sample of 30 locations. The mean location error of the person, who did most of the radio tracking, was 150 m (Kauhala and Tiilikainen 2002).

Data from Virolahti

In the snow-free season, we located raccoon dogs once every 15 min during dark hours to study their movements. The mean length of the tracking sessions was 5.0 h ± 1.19. We collected 1727 locations of 10 male and 11 female raccoon dogs during 121 tracking sessions in late March–early November (mainly April–October). We calculated the speed (m/h) and the area covered (minimum convex polygon) by each animal during each tracking session (including those with > 3 h, > 10 locations, > 2.5 locations/h). We used the software Ranges 6 (Kenward et al. 2003).

In winter (October 1–April 15) raccoon dogs were also located 2–3 times during dark hours (from 18:00 to 7:00) to see, whether they were moving ('active') or staying in their dens ('inactive'). We determined that an animal was inactive, if its distance from a known den was < 150 m and its position did not change during the particular night. Altogether we collected data of 323 'raccoon dog nights' (18 adult raccoon dogs, 8 males and 10 females) and calculated the frequency of active raccoon dog nights ('activity'). We are well aware of the fact that 'raccoon dog nights' are not independent in statistical sense. However, removing pseudo-replication would result in small data and thus unreliable conclusions. Furthermore, we assumed that each raccoon dog made the decision, whether to leave the den or not, regardless of its behaviour during the preceding tracking session, usually 1 or 2 weeks earlier. We also located raccoon dogs during daytime (214 locations) to gain additional data of their den use during winter. We examined the effect of weather (mean temperature of the day and snow depth), day length (the time between sunrise and sunset), and the phase of the moon on the activity of animals in winter, using the data from Virolahti. Weather data were obtained from a local weather station (Virolahti, Koivuniemi) of the Finnish Meteorological Institute (Ilmatieteen laitos/Sääpalvelut). We tested the effect of the moon on the activity of raccoon dogs only before the end of the year, because in midwinter raccoon dogs were usually lethargic (see Results) and we did not expect the moonlight to affect their activity during the harshest period of the year.

Data from Evo

We located the raccoon dogs usually 1–3 times per 24 h throughout the year (1990–1993). The transmitters used in Evo had activity sensors, giving about 60 beats per minute when the animal was resting (inactive) and about 90 beats per minute when the animal was moving (active). We determined, whether the animal was active or inactive, solely on the basis of the signal. When calculating the activity in winter, we took into account one location (signal) per animal per 24 h, the one taken latest at night, because if the animal was not in sleep, it usually started to move rather late in the evening. We gained data of 447 raccoon dog nights (20 animals, 7 males and 13 females) from Evo.

We also analysed circadian activity rhythm in different seasons using the data collected from Evo. We pooled the fixes of all animals (2612 fixes, 28 animals: 8 males and 20 females), grouped them in 2-h periods and divided the data into three seasons: winter (October 1–April 15, $n = 941$), breeding season (April 16–June 30, $n = 792$) and late summer (July 1–September 30, $n = 879$).

Statistical analyses

We tested the normality of sample distributions using Kolmogorov–Smirnov one sample test and then used ANOVA to test the differences between means. We used χ^2-test to analyse the differences between frequency distributions of categorical variables. When testing the effect of each environmental variable (day length, moon, temperature and snow depth) on the activity we divided the environmental variables into 8–9 classes (moon to 5 classes). We also performed discriminant analysis to see, whether raccoon dog nights could be classified as active or inactive on the basis of

weather and day length, using the original (not classified) values of the environmental variables. We used logistic regression to predict the probability of raccoon dogs being active on the basis of environmental variables (original values). The level of significance was set to 0.05.

Results

Seasonal movements and activity

Raccoon dogs moved fastest in late winter (March–April) and slowest in autumn (September–November; $F = 4.9$, $df = 8{,}122$, $P < 0.001$; Fig. 2). Speed of movements did not differ between the sexes ($P = 0.702$), nor did the interaction between sex and month have a significant effect on speed ($P = 0.119$). The area covered during each tracking session was largest in March ($F = 4.1$, $df = 8$, 112, $P < 0.001$), did not change from April to June ($P = 0.498$), but decreased with shortening days from July to November ($r = 0.44$, $df = 75$, $P < 0.001$).

In Virolahti, activity was lowest in mid-winter ($\chi^2 = 134.8$, $df = 6$, $P < 0.001$; Fig. 3A). Almost all raccoon dogs were still active in early October, and were moving again in the latter half of March. Most of them settled in their dens by December, sometimes wandering around also in mid-winter. The behaviour of sexes differed only in March when males were moving more often than females ($\chi^2 = 4.64$, $df = 1$, $P = 0.031$). Also in Evo, activity differed between months ($\chi^2 = 54.0$, $df = 6$, $P < 0.001$), but a fairly large proportion of signals indicated that the animals were active also in mid-winter (Fig. 3B).

Activity in relation to weather, day length and moon

In winter, activity differed according to day length ($\chi^2 = 122.8$, $df = 7$, $P < 0.001$), snow depth ($\chi^2 = 81.3$, $df = 8$, $P < 0.001$) and temperature ($\chi^2 = 82.1$, $df = 7$, $P < 0.001$; Fig. 4). Animals were usually inactive, when temperature was below $-10\,°C$, snow depth > 35 cm and day length < 7 h and active, when temperature was $> 0\,°C$, there was no snow and day length was > 10 h.

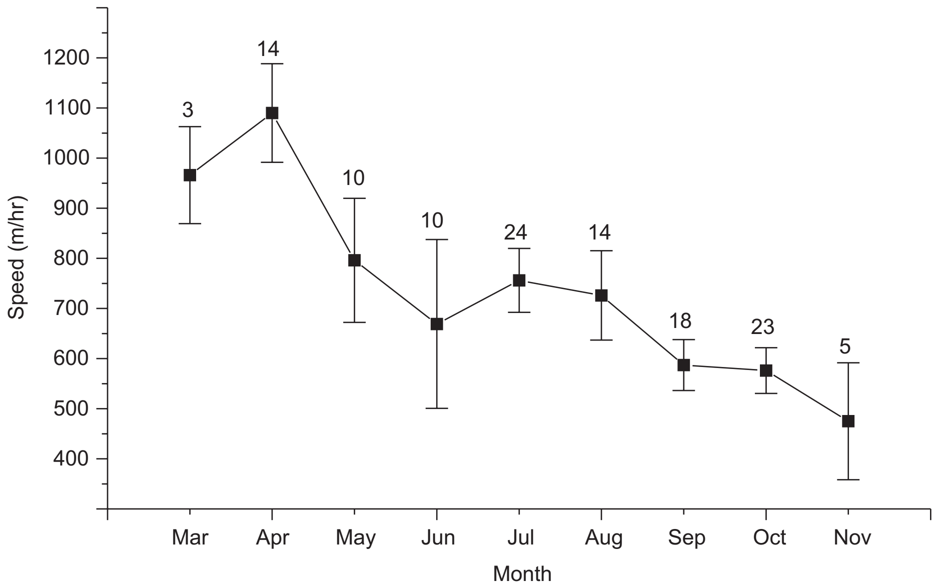

Fig. 2. Speed of raccoon dogs (mean ± SE) in different months during the snow-free season in Virolahti. The number of tracking sessions each month is also given.

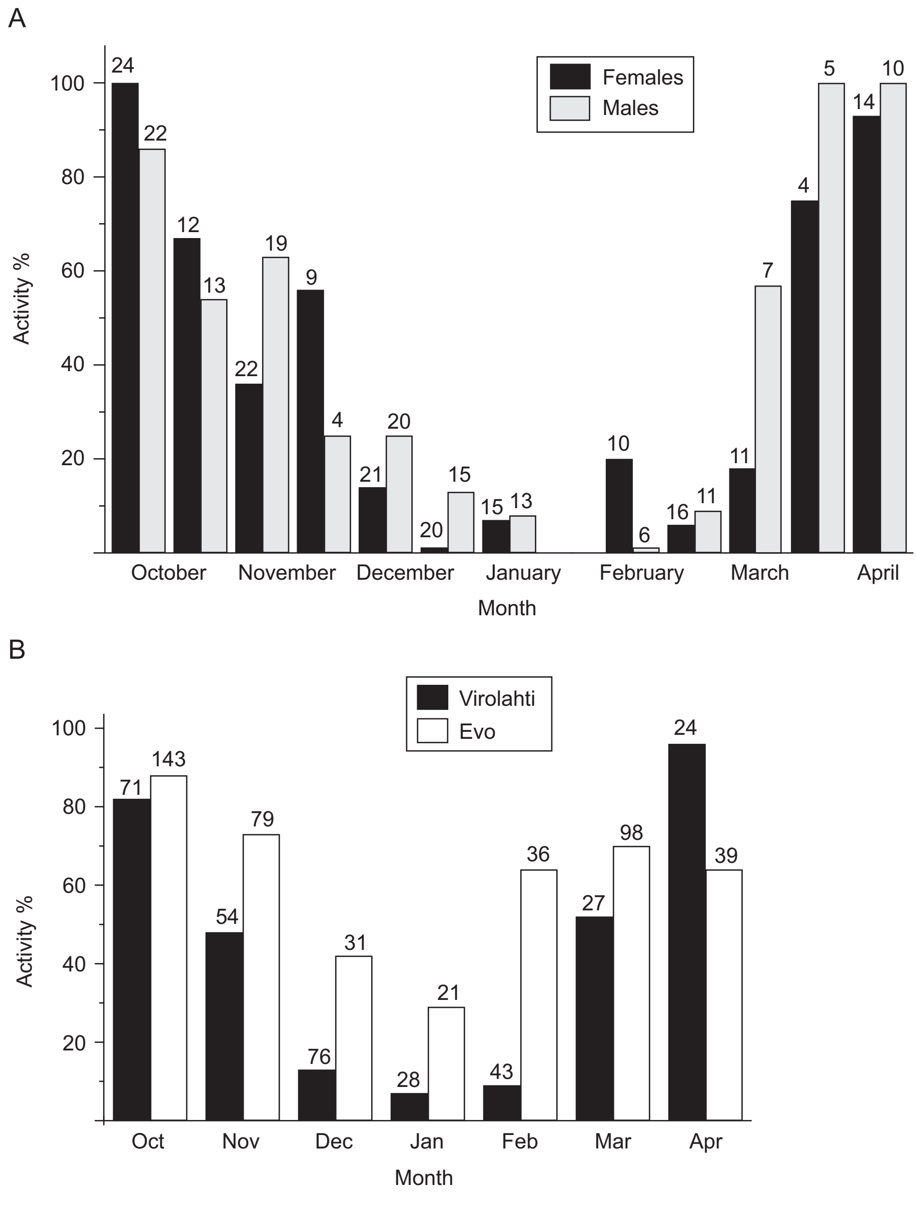

Fig. 3. Percent frequency of active 'raccoon dog nights' (activity %) in Virolahti in winter (October 1–April 15), determined using radio tracking. Each column indicates a period of about 2 weeks (the 2 first and the 2 last weeks of each month). The number of nights is given above the columns (A). Activity % in winter in Virolahti (2000–2003) and in Evo (1990–1993). The number of 'raccoon dog nights' is given above the columns (B).

Discriminant analysis resulted in 82% correct classification of raccoon dog nights into active and inactive using all three parameters (eigenvalue = 0.93, Wilks' lambda = 0.52, $F = 98.6$, df = 3, 319, $P < 0.001$). Logistic regression gave the equation: logit (activity

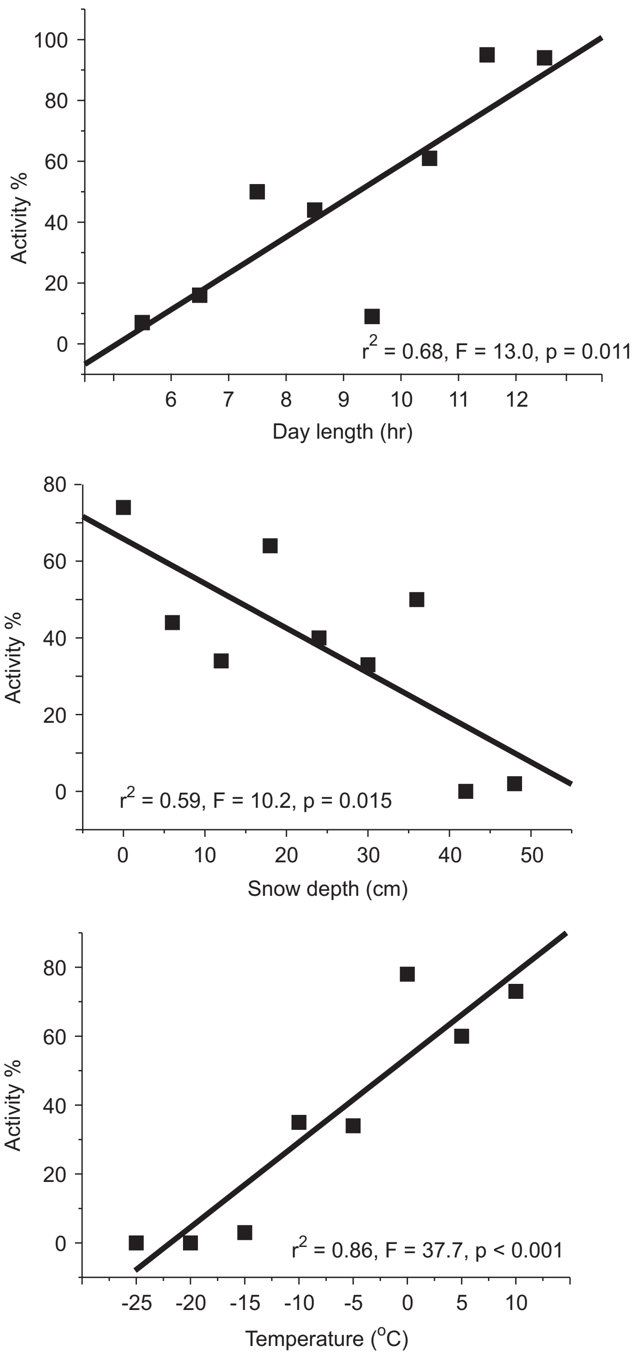

Fig. 4. Percent frequency of active 'raccoon dog nights' (activity %) in winter (October 1–April 15) in Virolahti in relation to day length, snow depth and temperature. The independent variables were classified into 8–9 groups and each dot gives the mean activity % for each group.

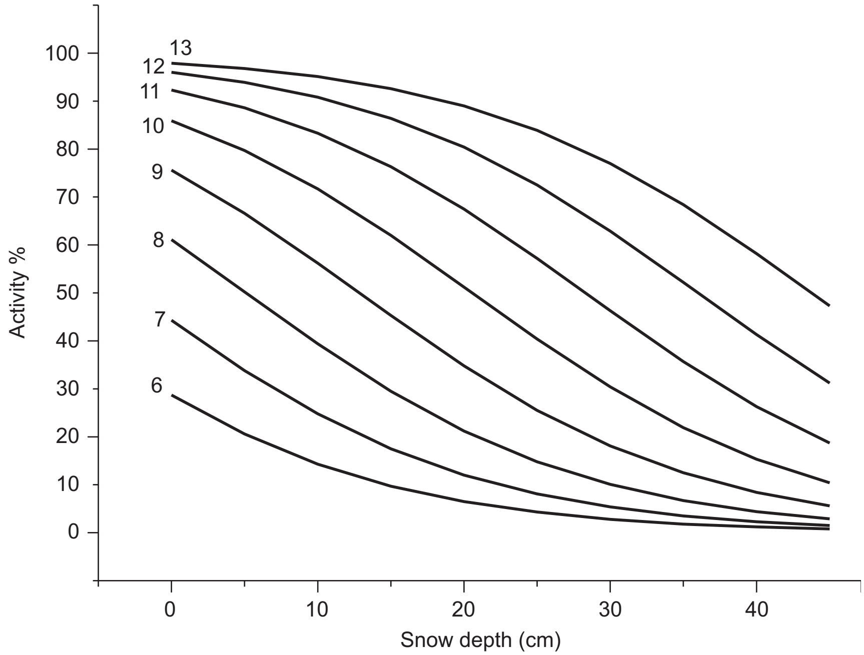

Fig. 5. The effect of snow depth and day length on the activity % during winter (October 1–April 15) in Virolahti. Different curves indicate different day lengths (6–13 h). The day length in southern Finland is a little less than 6 h in December 21 (the shortest day of the year) and exceeds 13 h in the beginning of April. Day length is 11.5 h in the beginning of October.

%) = –4.99 –0.088 × snow depth + 0.68 × day length (Fig. 5). We excluded temperature from the logistic regression analysis, because it correlated strongly with both day length and snow depth ($P<0.001$ for both). Snow depth and day length did not correlate ($P=0.999$).

Activity was highest (74%) during the period between new moon and half- moon ($\chi^2=12.5$, df = 4, $P=0.014$). Activity during new moon (±2 days) was 41%, during full moon (±2 days) 35%, during half-moon (±1 day) 40% and during the time between half-moon and full moon 48%.

Circadian activity rhythm in different seasons

Raccoon dogs (data for Evo) were moving more often during dark hours than in the daytime ($\chi^2=134$, df = 11.0, $P<0.001$). This was also tested separately for each season and both sexes ($P<0.001$ in all cases). A smaller proportion of signals indicated activity in winter than during the other seasons (males: $\chi^2=62.5$, df = 2, $P<0.001$, females: $\chi^2=42.8$, df = 2, $P<0.001$). In winter, activity level was lowest before midday (Fig. 6A). In the breeding season, raccoon dogs often seemed to rest early in the evening (around 18:00), whereas later in summer they usually rested in late afternoon (around 16:00). Activity level did not differ between sexes in the breeding season ($P=0.576$) or winter ($P=0.375$), but males were more often active than females in late summer, especially before noon ($\chi^2=8.9$, df = 1, $P=0.003$; Fig. 6B).

Winter dens

Raccoon dogs used the mean of 3.3 dens (SD = 1.99, range 1–9) and changed the den on average 3.0 times (SD = 2.53) during winter (animals with >5 locations during winter included). There was no difference

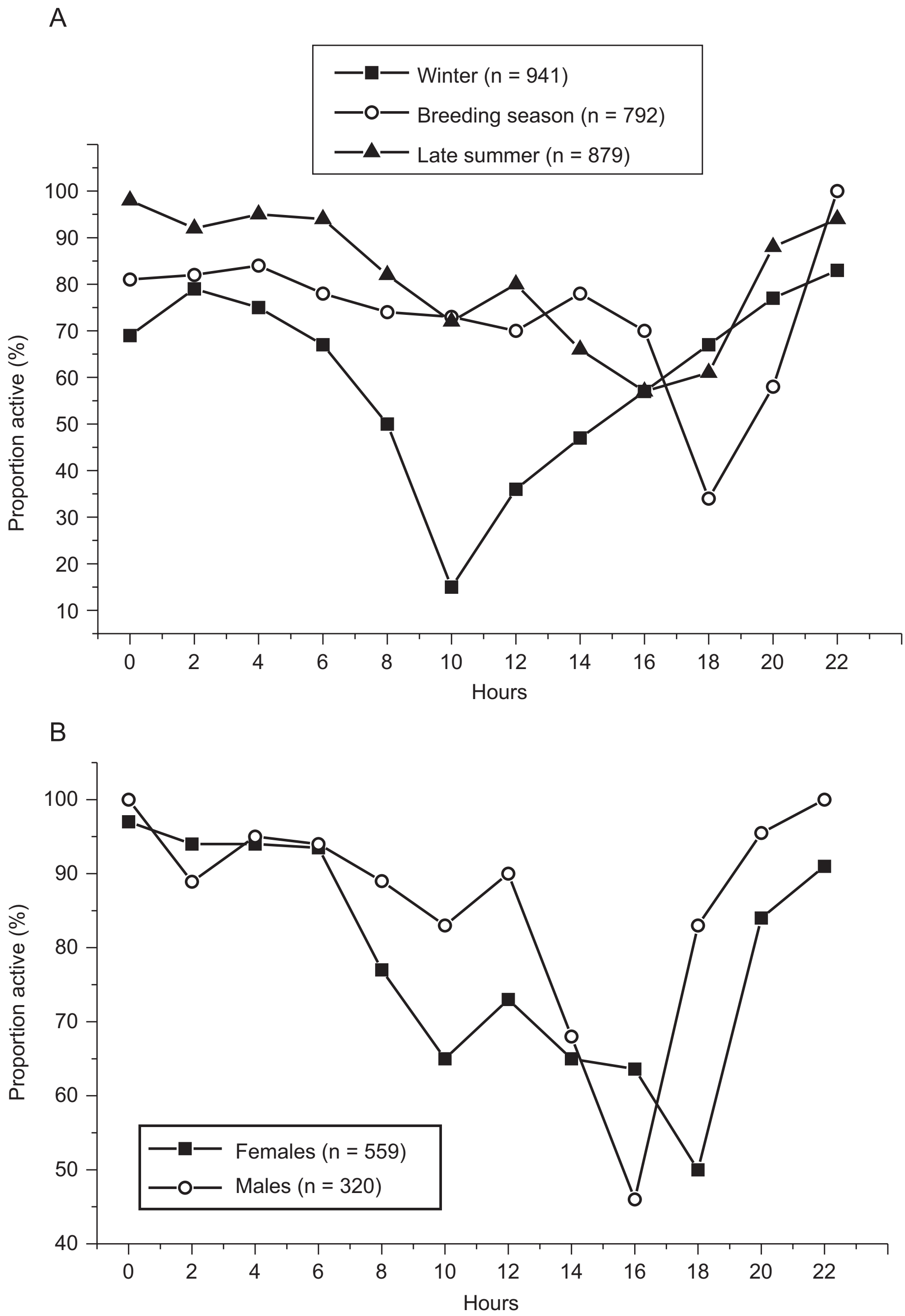

Fig. 6. Percent frequency of active signals in different times of day and in different seasons (A). Active signals (%) for males and females in late summer (B). The data was collected from Evo in 1990–1993.

between males and females in the number of dens used ($t = 0.70$, df $= 21$, $P = 0.495$).

Discussion

Winter lethargy

Raccoon dogs started their winter lethargy between late October and December, depending on weather, were least active between December and February and started to move again in March. Activity in winter (except during April) was, however, greater, when calculated for the data from Evo than for the data from Virolahti. The different method used probably explains this difference. In Virolahti, an animal was classified as inactive, if its position did not change during the particular night. In Evo, we determined the activity on the basis of one signal per night (active or inactive). The transmitters used in Evo were rather sensitive to slight movements of the animals, and may thus have indicated activity even when the animal was moving only inside the den. This points to the conclusion that the winter sleep of raccoon dogs is not very deep. They stay in the den in harsh periods of winter, but often move inside the den, falling into deep sleep only for short periods. When the dens were inspected after snow falls, we often saw footprints near the entrance, showing that the animals had considered the weather situation. If snow cover was deep and soft or if it was very cold, they had returned to the den. They have small paws and have difficulties to walk in deep, soft snow and their paws are very sensitive to frost bites (Korhonen and Harri 1989). But if the snow cover is hard, there are ski tracks to follow and it is not too cold, they may leave the den, walk longer distances and sometimes continue their winter lethargy in another den. They may, however, also fall into rather deep sleep for some time. Then their body temperature drops a few degrees and the metabolic rate decreases 25% (Heptner et al. 1974; Cerkasskij 1980).

In April, raccoon dogs were usually out of the den in Virolahti, but a rather high proportion of signals indicated inactivity in Evo. Snow melts later in Evo, which may well explain the difference. Before melting snow is very soft and raccoon dogs have difficulties to move.

Effect of weather, day length and moon on activity

Day length probably is the basic factor affecting the onset of winter lethargy in raccoon dogs. When the days shorten, the metabolism of raccoon dogs changes, they put on weight and, when a sufficient amount of fat has been stored, they start winter lethargy (Korhonen 1988). Besides day length, both temperature and snow depth affected activity of raccoon dogs in winter. Also Korhonen (1988) found that activity of raccoon dogs increased in warm periods in winter, indicated by increased food intake.

If climate is warming, winters in southern Finland will become milder and there will be more rain and less snow. This will most probably shorten the winter lethargy of raccoon dogs and winter sleep will be frequently interrupted by warm periods during winter. Raccoon dogs will also move between different dens more often, especially if it is raining and water enters their dens. Raccoon dogs are known to be active throughout the winter in Germany, where winters are milder and cold periods with snow are shorter and less frequent than in Finland. In Poland, where winters are more severe than in Germany, raccoon dogs are lethargic from December to February or March, depending on the weather (Jedrzejewska and Jedrzejewski 1998).

The moon also affected activity of raccoon dogs in early winter. Raccoon dogs preferred to move around when there was some, but not too much, moonlight. Because raccoon dogs are commonly hunted in Finland and are also prey for larger predators, they probably avoid moving in bright moonlight. They may also feel unsafe at very dark nights without any moonlight at all.

Seasonal movements and spread of diseases and parasites

The probable increase of movements during winter, if climate is in fact warming, may accelerate the spread of rabies and other diseases and parasites. It is not actually known, what happens to rabies virus during winter lethargy of raccoon dogs, but it has been suspected that the virus can pass the

winter in latent phase (Cerkasskij 1980). However, if the winter is long and the animals stay in their dens throughout the winter, the contact rate probably falls below a critical value (=1) and the epizootic may cease. (Contact rate = the mean number of healthy animals that a diseased animal infects.) But if the period of winter lethargy will become shorter and animals will frequently move around in winter, contact rate will possibly be high enough in winter to maintain the epizootic. Furthermore, even today raccoon dogs now and then change the winter den and sometimes share dens with badgers (Kowalczyk et al. 2000, Kauhala and Holmala 2006) and may thus transmit the disease to other individuals in the carnivore community.

Adult raccoon dogs moved fastest and used largest areas in March and April. This may be due to the mating season and to food shortage after winter. If the rabies virus did not die out from the population during winter, raccoon dogs may efficiently spread it during the mild nights of late winter. An annual peak in the occurrence of raccoon dog rabies has indeed been found in late winter (Westerling 1991; Reinius 1992; WHO 2003, 2004). Another peak is in autumn, when juveniles disperse (Kauhala et al. 1993; Drygala et al. 2000). Because adult raccoon dogs decreased their movements to smaller areas towards autumn, the autumn peak in rabies occurrence must be due to dispersal of juveniles. Also Korhonen (1987) found that raccoon dogs (in a fur farm) decreased their movements before winter sleep. Unlike rabies, which is transmitted in direct contact, *E. multilocularis* spreads through eggs in carnivore faeces. Rodents are intermediate hosts, which are infected when consuming the eggs. Foxes (*Vulpes vulpes*) or raccoon dogs that consume the rodents may then be infected again. When winters are cold and raccoon dogs are asleep, they do not eat and produce faeces. But if climate is warming, raccoon dogs will be more often active, and may thus spread the parasite also in winter. Moreover, because raccoon dog density will probably increase with rising temperatures (Kauhala and Helle 1995), there will be more raccoon dogs wandering around and transmitting the parasite.

Circadian activity rhythm

Raccoon dogs were more often active at night than in the daytime, but they were moving also during light hours, especially in the snow-free season. Also Drygala et al. (2000) found that although raccoon dogs were mainly nocturnal in Germany, they also showed rather much diurnal activity. Ward and Wurster-Hill (1989) found that Japanese raccoon dogs were also often active in the daytime, especially in the morning and late afternoon. Daytime activity may be due to the fact that raccoon dogs are not specialized hunters but true omnivores. Predators usually hunt during the darkness of night to be able to surprise their prey, but omnivore gatherers also move in the daytime, usually through thick vegetation, in search for their small food items. Especially when they are hungry, as after winter sleep and during pup-rearing, they frequently roam during daylight (Novikov 1962).

Acknowledgements

We are grateful to the field assistants and hunters, who helped us in the field. The Ministry of Agriculture and Forestry, the Science Foundation of Helsinki University and the Finnish Cultural Foundation gave financial support.

Zusammenfassung

Saisonale Aktivitäts- und Bewegungsmuster des Marderhundes, einer Vektorspezies von Krankheiten und Parasiten, in Süd-Finnland

Die Aktivitäts- und Bewegungsmuster des Marderhundes (*Nyctereutes procyonoides*) wurden in den Jahren 2000 bis 2003 in Virolahti, Südost-Finnland, untersucht. Die Aktivitätsdaten wurden mit den

entsprechenden Daten einer Studie von 1990 bis 1993 in Evo, südliches Mittelfinnland, verglichen. Des weiteren wurde die Aktivität im Winter mit dem Wetter, der Tageslänge und den Mondphasen in Zusammenhang gebracht. In Evo wurden ausserdem circadiane Aktivitätsrhythmen untersucht. Die Marderhunde bewegten sich am schnellsten im Spätwinter nach der Winterruhe und am langsamsten im Herbst vor der Winterruhe. Im März bewegten sich Männchen häufiger als Weibchen. In der Mitte des Winters (Dezember–Februar) blieben die Tiere normalerweise in ihrem Bau, wanderten aber auch manchmal in den härtesten Monaten des Jahres umher und wechselten ihre Schlafplätze im Schnitt dreimal im Laufe des Winters. Sowohl Tageslänge als auch Witterung (Temperatur und Schneehöhe) beeinflussten die Aktivität der Marderhunde im Winter. Die Tiere blieben gewöhnlich im Bau, wenn die Temperaturen unter $-10\,^{\circ}$C, die Schneehöhe über 35 cm und die Tageslänge unter 7 Std. waren. Wenn die Temperaturen $>0\,^{\circ}$C waren, kein Schnee lag und die Tageslänge über 10 Std. war, wurden die Tiere aktiv. Anhand der Tageslänge und der Schneehöhe konnte die Aktivität der Marderhunde im Winter recht genau vorhergesagt werden. Obwohl Marderhunde überwiegend nachtaktiv waren, zeigten sie häufig auch tagsüber Aktivität.

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